# Appendix O. Setting the Chlorophyll *a* Criteria-Based Nutrient Allocations for the James River Watershed

The initial Draft Target Load Allocation of 190 million pounds per year (mpy) total nitrogen (TN) and 12.7 mpy total phosphorus (TP) was determined on the basis of attainment of Chesapeake Bay basin-wide numeric dissolved oxygen standards. At that loading level, an assessment of predicted chlorophyll *a* concentrations showed nonattainment of Virginia's numeric chlorophyll *a* water quality standard in the James River for several 3-year assessment periods, in multiple segments and in both spring and summer seasons (see Figure 1). The narrative rationale for Virginia's numeric chlorophyll *a* criteria (see Table 1) is described in EPA's 2003 *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll* a *for the Chesapeake Bay and Its Tidal Tributaries* (USEPA 2003a).

| Cbseg | 190 Loading Scenario 190TN, 12.7TP, 6030TSS '91-'93 CL Spring Seasonal | 190 Loading Scenario 190TN, 12.7TP, 6030TSS '92-'94 CL Spring Seasonal | 190 Loading Scenario 190TN, 12.7TP, 6030TSS '93-'95 CL Spring Seasonal | 190 Loading Scenario 190TN, 12.7TP, 6030TSS '94-'96 CL Spring Seasonal | 190 Loading Scenario 190TN, 12.7TP, 6030TSS '95-'97 CL Spring Seasonal | 190 Loading Scenario 190TN, 12.7TP, 6030TSS '96-'98 CL Spring Seasonal | 190 Loading Scenario 190TN, 12.7TP, 6030TSS '97-'99 CL Spring Seasonal | 190 Loading Scenario 190TN, 12.7TP, 6030TSS '98-'00 CL Spring Seasonal |
|---|---|---|---|---|---|---|---|---|
| JMSTFL | 0% | 0% | 2% | 2% | 2% | 0% | 0% | 0% |
| JMSTFU | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSOH | 0% | 0% | 0% | 4% | 4% | 4% | 0% | 5% |
| JMSMH | 3% | 1% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSPH | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **Cbseg** | **CL Summer Seasonal** | **CL Summer Seasonal** | **CL Summer Seasonal** | **CL Summer Seasonal** | **CL Summer Seasonal** | **CL Summer Seasonal** | **CL Summer Seasonal** | **CL Summer Seasonal** |
| JMSTFL | 0% | 0% | 0% | 0% | 5% | 15% | 15% | 8% |
| JMSTFU | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSOH | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSMH | 0% | 0% | 0% | 0% | 0% | 0% | 15% | 14% |
| JMSPH | 0% | 0% | 0% | 0% | 0% | 0% | 11% | 11% |

For this scenario, the James River Basin allocation is 26.6 mpy TN and 2.7 mpy TP. Failure to attain water quality standards is shown in red text as percent nonattainment.

**Figure 1. Attainment of numeric chlorophyll *a* water quality standards in the James River at the draft Target Load Chesapeake Bay basin-wide allocation of 190 mpy TN and 12.7 mpy TP.**

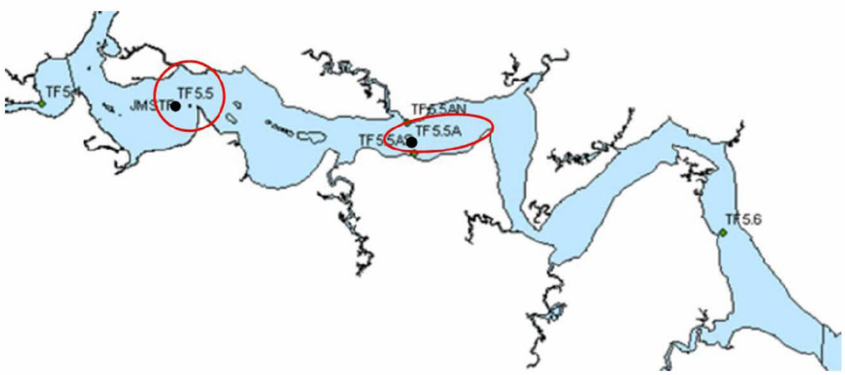
**Table 1. James River numeric chlorophyll *a* criteria**

| Segment | Seasonal mean criterion (µg/L) spring/summer |
|---|---|
| JMSTFU | 10/15 |
| JMSTFL | 15/23 |
| JMSOH | 15/22 |
| JMSMH | 12/10 |
| JMSPH | 12/10 |

µg/L = micrograms per liter

To identify the level of load reductions necessary to achieve chlorophyll *a* water quality standards (WQS) in the James River, the EPA Chesapeake Bay Program's (CBP's) modeling and monitoring teams investigated the underlying drivers of those remaining instances of nonattainment.

First, the drivers of nonattainment in the lower tidal fresh James during the spring for the three assessment periods spanning 1993–1997 were examined. For all three assessment periods, failure to attain the WQS at draft target loading levels was driven by conditions and estimated levels of improvement in the spring of 1995 at stations TF5.5 and TF5.5A, where chlorophyll *a* concentrations exceeding the seasonal mean chlorophyll *a* criterion of 15 µg/L were observed.




Stations TF5.5 and TF5.5A are marked with black dots and circled in red.

**Figure 2. James Tidal Fresh Lower (JMSTFL) segment of the James River, with long-term fixed monitoring stations shown.**

CBP analysts next investigated whether the estuarine Water Quality Sediment Transport Model (WQM) was sufficiently calibrated to observed conditions in that region of the James River. A comparison of observed values at station TF5.5 with those generated by the WQM during its calibration run demonstrated that the WQM simulated the range of surface chlorophyll *a* conditions experienced in the region in 1995 (Figure 3).

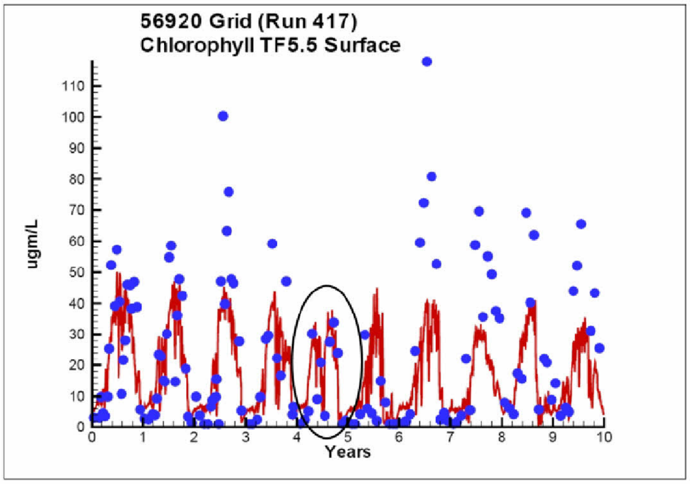



**Figure 3. Plot comparing WQM-simulated surface chlorophyll *a* values (red line) with historical observations (blue dots). For the year 1995 (circled in black), simulated values captured the range of observed conditions.**

Furthermore, a comparison of the WQM's response to load reductions in the region showed a consistent response in the form of a reduction of undesirable surface chlorophyll *a* levels (i.e., those exceeding the seasonal mean criterion) when loads were reduced (see Table 2). From those lines of evidence, it was determined that this instance of nonattainment represented a best available estimate of remaining nonattainment in the JMSTFL for the spring seasons of 1993–1995, 1994–1996, and 1995–1997 periods. Those periods reached attainment of WQS with the *170 TN, 11.3TP Loading Scenario*, for which James River Basin loads were 35.5 mpy TN and 2.5 mpy TP. At that loading level, some individual surface chlorophyll *a* values exceeded the seasonal mean criterion, but the average seasonal degree of criteria violation fell within the allowable exceedance of 1 percent.

**Table 2. Observed and scenario-modified chlorophyll *a* concentrations (µg/L) at stations TF5.5 (a) and TF5.5A (b) in the spring of 1995. The 26.6 TN, 2.7 TP loading level represents James River Basin load reductions for the global 190 TN, 12.7 TP**

(a)

| TF5.5 | | | |
|---|---|---|---|
| Month | observed | 26.6 TN 2.7 TP | 25.5 TN 2.5 TP |
| March 1995 | 5.1 | 5.5 | 5.6 |
| April 1995 | 30.2 | 18.8 | 17.7 |
| May 1995 | 9.1 | 7.7 | 7.2 |

(b)

| TF5.5A | | | |
|---|---|---|---|
| Month | observed | 26.6 TN 2.7 TP | 25.5 TN 2.5 TP |
| March 1995 | 48.7 | 29.7 | 26.8 |
| April 1995 | 38.8 | 21.8 | 20.3 |
| May 1995 | 7.7 | 9.6 | 9.2 |

**loading**

Verification of the violations described above, and determination of their resolution at the James River-specific loading level of 25.5 mpy TN and 2.5 mpy TP, enabled EPA CBP analysts to confirm a minimum required reduction scenario for James River to this loading level. Next, remaining violations at the 25.5 mpy TN/2.5 mpy TP loading level (170 Loading Scenario) were investigated. In order to determine the maximum necessary additional loading reductions, analysts focused on the greatest remaining levels of nonattainment—those occurring for the summer season in JMSTFL, JMSMH, and JMSPH (see Figure 4).

| Cbseg | 170 Loading Scenario 25.5 TN, 2.5TP '91-'93 CL Spring Seasonal | 170 Loading Scenario 25.5 TN, 2.5TP '92-'94 CL Spring Seasonal | 170 Loading Scenario 25.5 TN, 2.5TP '93-'95 CL Spring Seasonal | 170 Loading Scenario 25.5 TN, 2.5TP '94-'96 CL Spring Seasonal | 170 Loading Scenario 25.5 TN, 2.5TP '95-'97 CL Spring Seasonal | 170 Loading Scenario 25.5 TN, 2.5TP '96-'98 CL Spring Seasonal | 170 Loading Scenario 25.5 TN, 2.5TP '97-'99 CL Spring Seasonal | 170 Loading Scenario 25.5 TN, 2.5TP '98-'00 CL Spring Seasonal |
|---|---|---|---|---|---|---|---|---|
| JMSTFL | 0% | 0% | 1% | 1% | 1% | 0% | 0% | 0% |
| JMSTFU | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSOH | 0% | 0% | 0% | 2% | 2% | 2% | 0% | 2% |
| JMSMH | 2% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSPH | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Cbseg | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal |
| JMSTFL | 0% | 0% | 0% | 0% | 4% | 11% | 11% | 4% |
| JMSTFU | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSOH | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSMH | 0% | 0% | 0% | 0% | 0% | 0% | 12% | 12% |
| JMSPH | 0% | 0% | 0% | 0% | 0% | 0% | 9% | 9% |

For this scenario, the James River Basin allocation is 25.5 mpy TN and 2.5 mpy TP. Failure to attain WQS is shown in red text as percent nonattainment.

**Figure 4. Attainment of numeric chlorophyll *a* WQS in the James River at the Chesapeake Bay basin-wide loading level of 170 mpy TN and 11.3 mpy TP.**

Using the same systematic procedure employed for the JMSTFL violations described above, the 12 percent nonattainment observed for JMSMH in the summers of 1997–1999 and 1998–2000 was examined. The primary driver of the nonattainment was traced to conditions occurring at James River monitoring stations LE5.2 and LE5.3 in September 1999. Examination of observed and scenario-modified data for the summer of 1999 in the region of LE5.2 and LE5.3 showed that individual historical observations did in some cases exceed the summer seasonal mean criterion of 10 μg/L for JMSMH. But more importantly, the regression equations used to scenario-modify chlorophyll *a* concentrations (for details on the scenario-modification procedure, see Chapter 6.4) at the stations in September 1999 were generating *higher* chlorophyll *a* concentrations with reduced loads rather than lower concentrations.

A comparison of the WQM simulation against observed values at LE5.3 showed that the WQM simulated the range of surface chlorophyll *a* conditions observed in 1999 (see Figure 5). For the year 1999 (circled in black), simulated values captured the range of observed conditions.

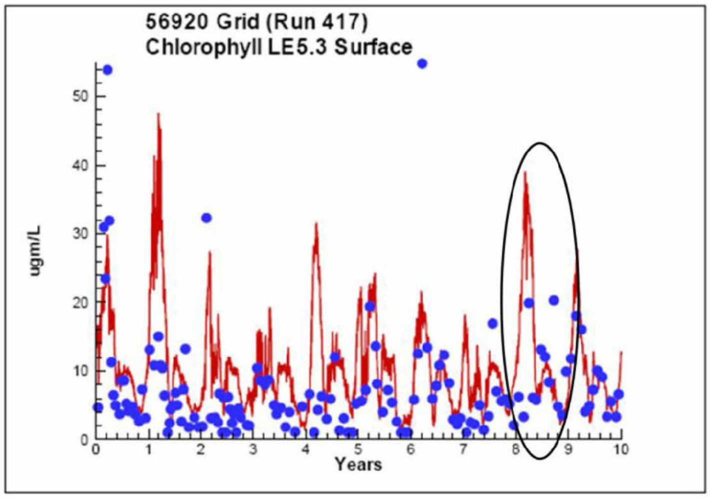



**Figure 5. Plot comparing WQM-simulated surface chlorophyll a values (red line) with historical observations (blue dots).**

A closer look at simulated surface conditions at LE5.2 and LE5.3 in the summer of 1999 showed that from June through early September, simulated chlorophyll *a* concentrations were within the range or moderately lower than observed surface chlorophyll *a* values and that chlorophyll *a* concentrations consistently declined when loads were reduced. However, an anomaly occurred in some driver of the model simulation that caused poor scenario performance in the latter half of September 1999 at LE5.2 (see Figure 6) and, to a lesser degree, LE5.3 (not shown). Specifically, chlorophyll *a* concentrations suddenly increased in all scenarios, and concentrations for the load reduction scenarios increased to even higher levels than for the calibration scenario.

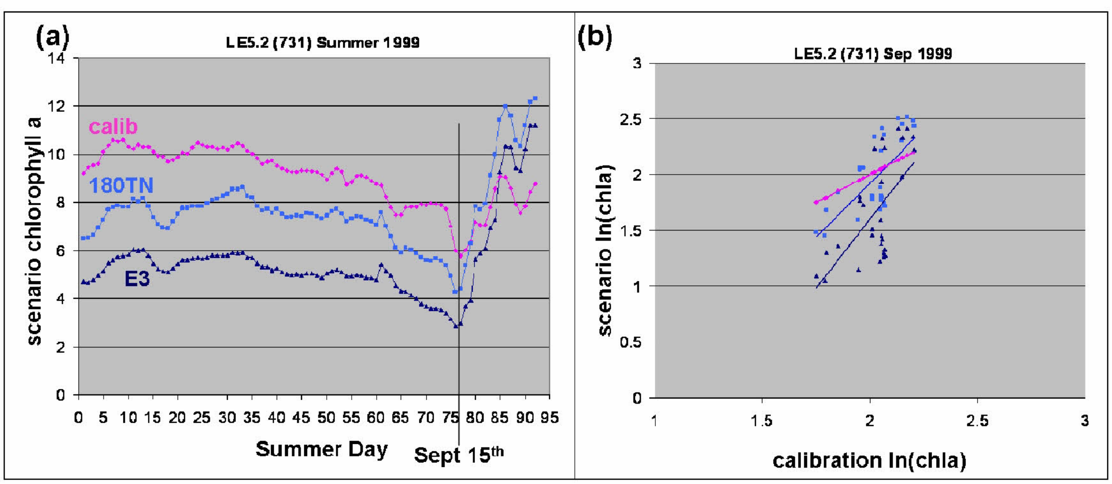



**Figure 6. Plot of simulated surface chlorophyll *a* concentrations for WQM cell 731 (location of station LE5.2) during the summer of 1999 (a), and resulting regression plot for September 1999 LE5.2 chlorophyll *a* (b).**

For most of the summer, load reduction scenarios such as the 179 TN/12.0 TP loading scenario (light blue symbols and line, *180 TN*) and the E3 scenario (dark blue symbols and line, *E3*) simulated consistently reduced surface chlorophyll *a* concentrations relative to the calibration scenario (pink symbols and line, *calib*). After September 15, load reduction scenarios generated higher chlorophyll *a* concentrations than the calibration scenario. As a result, regression equations used to scenario-modify chlorophyll *a* observations from September 1999 generated higher chlorophyll *a* concentrations under reduced loading scenarios.

The effect of that anomaly was to generate flawed regression equations for the September period which caused chlorophyll *a* observations to be scenario-modified to higher rather than lower concentrations under reduced-load scenarios (see Table 3).

**Table 3. Observed, scenario-modified (190 TN), and refined scenario-modifed chlorophyll *a* concentrations at LE5.2 in summer 1999**

| **LE5.2** | **chlorophyll *a* (µg/L)** | | |
|---|---|---|---|
| Month | Observed | 190 TN | 190 TN, refined |
| July 1999 | 11.1 | 8.94 | 8.94 |
| August 1999 | 6.19 | 5.34 | 5.34 |
| September 1999 | 14.0 | 23.7 | 10.8 |

When the anomalous data generated after September 15 were removed from the analysis, the resulting regression equations better reflected the information provided by the WQM with regard to predicted improvements in chlorophyll *a* concentrations with reduced pollutant loads. Using the *refined regression* for September 1999, the percent nonattainment of 12 percent for JMSMH in the summer 1997–1999 and 1998–2000 summer periods shown in Figure 5 declined to only 2 percent at the 170 Loading Scenario level of 25.5 mpy TN and 2.5 mpy TP for the James River Basin.

As with the violations described for JMSTFL above, the newly verified nonattainment levels were used to identify further load reductions required to achieve attainment of summer seasonal WQS in JMSMH. Scenarios were generated with progressively more stringent load reductions. Attainment of summer seasonal chlorophyll *a* WQS was achieved in JMSMH for the 1997–1999 and 1998–2000 assessment periods at the 23.5 TN, 2.35 TP loading level for the James River Basin (see Figure 7).

| Cbseg | 23.5 TN 2.35 TP '91-'93 CL Spring Seasonal | 23.5 TN 2.35 TP '92-'94 CL Spring Seasonal | 23.5 TN 2.35 TP '93-'95 CL Spring Seasonal | 23.5 TN 2.35 TP '94-'96 CL Spring Seasonal | 23.5 TN 2.35 TP '95-'97 CL Spring Seasonal | 23.5 TN 2.35 TP '96-'98 CL Spring Seasonal | 23.5 TN 2.35 TP '97-'99 CL Spring Seasonal | 23.5 TN 2.35 TP '98-'00 CL Spring Seasonal |
|---|---|---|---|---|---|---|---|---|
| JMSTFL | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSTFU | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSOH | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSMH | 1% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSPH | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| **Cbseg** | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal | CL Summer Seasonal |
| JMSTFL | 0% | 0% | 0% | 0% | 2% | 6% | 6% | 2% |
| JMSTFU | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSOH | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| JMSMH | 0% | 0% | 0% | 0% | 0% | 0% | 1% | 1% |
| JMSPH | 0% | 0% | 0% | 0% | 0% | 0% | 9% | 9% |

**Figure 7. Attainment stoplight plot of James River chlorophyll *a* WQS for the 23.5 TN, 2.35 TP load reduction scenario. Highlighted fields show attainment in JMSMH for summers 1997–1999 and 1998–2000.**

At this load reduction level, two blocks of nonattainment remained: JMSTFL summer for the assessment periods 1995–1997 through 1998–2000, and JMSPH summer for the assessment periods 1997–1999 and 1998–2000.

Summer nonattainment in JMSPH for assessment periods 1997–1999 and 1998–2000 was traced to conditions at station LE5.4W in the summer of 1999. Chlorophyll *a* concentrations in this region consistently exceeded the summer seasonal mean criterion for JMSPH of 10 µg/L (see Table 4).

**Table 4. Observed and scenario-modified chlorophyll *a* concentrations at LE5.5-W in the summer of 1999.**

| **LE5.5W** | **chlorophyll *a* (µg/L)** | | |
|---|---|---|---|
| Month | Observed | 26.6 TN, 2.7 TP | 25.5 TN/2.5 TP |
| July 1999 cruise 1 | 14.7 | 11.9 | 11.3 |
| July 1999 cruise 2 | 22.7 | 19.3 | 18.3 |
| Aug 1999 cruise 1 | 12.9 | 9.98 | 9.48 |
| Aug 1999 cruise 2 | 14.2 | 11.0 | 10.4 |
| September 1999 | 39.2 | 15.5 | 14.0 |

When historical observations fall well outside the range of concentrations simulated by the water quality model, the WQM's ability to estimate the predicted magnitude of response to reduced loads is compromised. Some of the concentrations observed at LE5.5W in the summer of 1999 were within the range of the WQM simulations. However the September 1999 observation of 39.2 µg/L was well outside the range of simulated conditions, reducing confidence in estimates of expected improvement in chlorophyll *a* concentrations. While concern remains regarding these clear violations of chlorophyll *a* WQS, insufficient information exists to justify further load reductions from estimates of remaining nonattainment for JMSPH in the 1997–1999 and 1998–2000 assessment periods.

The case of remaining summer nonattainment in JMSTFL is similar to that of JMSPH but even more pronounced. Remaining nonattainment could be traced back to summer conditions in 1997 and 1998, when surface chlorophyll *a* concentrations regularly exceeded the summer seasonal mean criterion of 23 μg/L. In Figure 3, summer observations ranging from about 50 to more than 100 μg/L can be seen to far exceed the WQM's simulated average summer conditions for this region. Similarly, conditions at station TF5.5A ranged from 75.6 to 113 μg/L in the summer of 1997. Such bloom conditions exceed the range of simulated conditions to such a degree that it is difficult to predict the expected magnitude of improvement with load reductions. Therefore, insufficient information exists to justify further load reductions on the basis of estimates of remaining nonattainment for JMSTFL in these summer assessment periods.

Using the information gained from the analyses described above, the chlorophyll *a*-based nutrient load allocations for the James River Basin were set at 23.5 mpy TN and 2.35 mpy TP. At that load allocation, verified events of nonattainment in JMSTFL for the spring seasons of 1993–1995, 1994–1996, and 1995–1997, as well as verified events of nonattainment in JMSMH for the summer seasons of 1997–1999 and 1998–2000, were resolved. Regions with remaining instances of nonattainment (i.e., JMSTFL and JMSPH summer seasonal conditions) will be closely monitored in coming years to ensure that the allocated load reductions result in the conditions necessary to achieve attainment of chlorophyll *a* water quality standards.